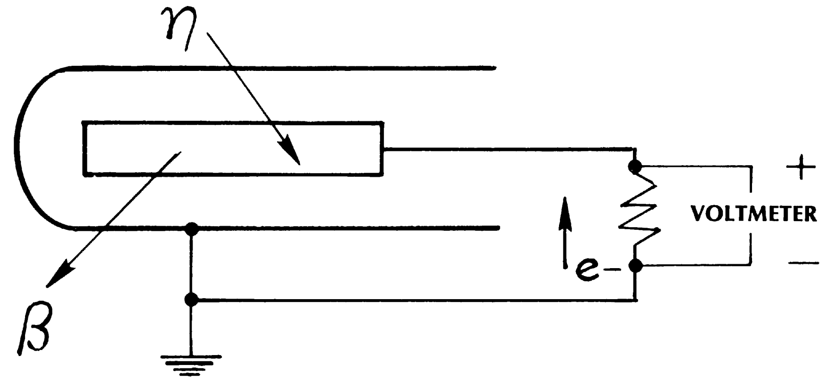
ARi Industries Inc



SELF POWERED NEUTRON DETECTORS*

FOR:
- **Reactor incore flux measurement.**
- **Rugged, flexible, simple, long lived, point or average sensing.**
- **Indication or control.**
- **High flux—high temperature use.**
- **Mapping or permanent installation.**

ARi produced SPND's have several unique features:

The sheath is continuous over the emitter and lead section —even when the sections are different diameters.

The attachment of the emitter to the lead is made using a patented process that requires no additional materials to be added.

Continuous insulation throughout the detector—fully compressed to offer a maximum insulation resistance over the full temperature range.

No braze materials are present to scatter neutrons and cause errors.

No voids are present to induce gamma heating and lower the insulation resistance.

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BULLETIN 10.3

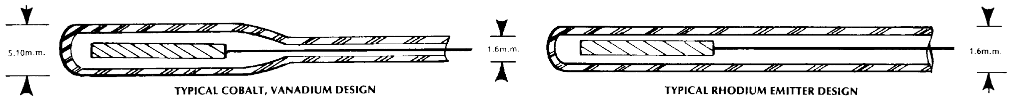
NEUTRON DETECTORS

SELF POWERED NEUTRON DETECTORS

Self-powered neutron detectors are devices that produce a positive charge on an electrode by emitting electrons when exposed to radiation. When the electrode has a high activation cross section for (η ,B) reactions, electrons will flow from it and produce an electron current which is proportional to the neutron flux. The electrons flow up the wire attached to the electrode replacing escaping beta particles (beta decay). The term "self-powered" is derived from the induced current produced in the irradiation.

The main components of a self-powered neutron detector system are a metallic sheath (collector) which surrounds a coaxial insulant that isolates and electrically insulates the emitter and its connected leadwire. (See fig. 1)

Fig. #1 Coaxial Neutron Detectors



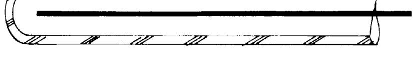
TYPICAL COBALT, VANADIUM DESIGN

TYPICAL RHODIUM EMITTER DESIGN

For greatest accuracy in a self-powered neutron detector system a background detector should be initially included to measure the flow of parasitic electrons produced by all of the materials in the system.

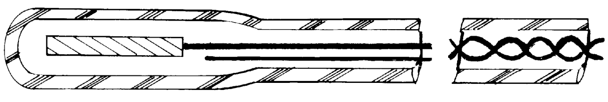
A background detector is of identical construction as the self-powered neutron detector except that the emitter is not included. (See fig. 2)

Fig. #2 Background Detector



For some special applications the emitter and background detector can be enclosed in the same sheath—generally without an increase in the outside sheath diameter. The two wires may be parallel or spiralled around each other. (See fig. 3)

Fig. #3 Biaxial Neutron Detector

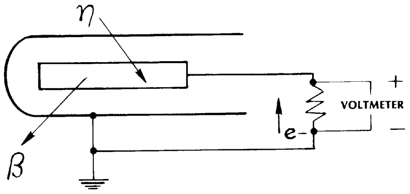


PARALLEL

ALTERNATE SPIRALED LEADS

The electron current signal produced can be read out on a millivoltmeter, a multipoint recorder, a data logger or a computer. The attachment of the detectors to the read out device is achieved by adding a dropping resistor between the emitter and ground. (See fig. 4)

Fig. #4 **Typical Circuit**



The amount of the neutron flux measured depends on the choice of sensitive material used for the emitter its purity, mass and dimensions.

The response time, which is defined as the time necessary for an emitter to indicate 63% of a neutron flux step function (instantaneous variation) is dependent on the half-life of the radioisotope created by the irradiation of the emitter material. Various emitter materials and their characteristics are shown in table II.

All emitter materials gradually lose sensitivity because of burn-up, but their burn-up rate is less than the fuel burn-up rate. Rhodium, for example, will last more than four times longer than U235. Emitter life is primarily a function of the depletion rate and is directly proportional to the expended current. For rhodium, the depletion rate curve is mathematically well enough defined so that a detector's remaining sensitivity can be determined.

When cobalt is selected as the emitter material, compton and photo electrons will be emitted during irradiation by internal conversion of gamma rays produced when a neutron is captured. The escaping electrons cause a positive charge to be induced on the emitting electrode. The gamma rays are emitted in 10^{-14} seconds for cobalt. Because of this quick response, self-powered neutron detectors with cobalt emitters are called prompt neutron detectors.

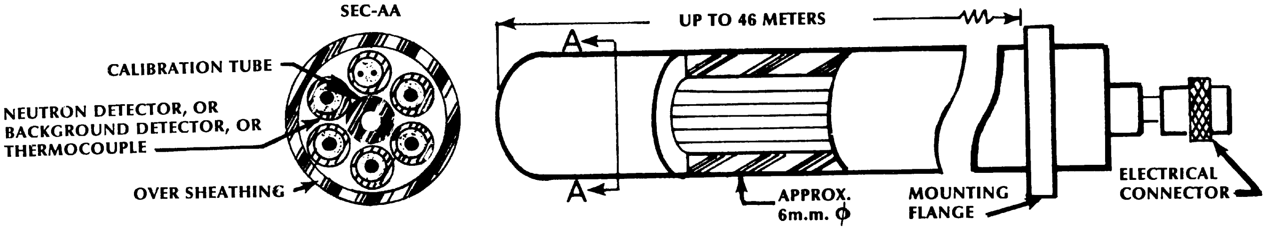
The diameter range of emitter materials is limited because electrons emitted deep in the electrode may not have sufficient range to escape. Average diameters of rhodium, vanadium and cobalt emitters that have performed acceptably in water moderated reactors are 0.5mm (.020″), 1.0mm (.040″) and 2.0mm (.080″) respectively. With emitter diameter at a maximum; length, and the corresponding mass of the emitter are the main variables for sensitivity adjustment. The minimum design length of the detector is based on the flux field and must produce a signal large enough to overcome parasitic signals and insulation resistance drop due to operating temperature. The maximum emitter length is limited by the reactor or loop design.

Sheath and collector materials are commonly 300 series stainless steel or Inconel* with purities for low neutron capture cross section. The sheath material should be compatible with the reactor coolant and wall thickness must be heavy enough to hold the ceramic insulation in compaction. A relatively heavy sheath wall may be useful in reducing parasitic currents that can be produced if the detector is operated in a protective tube which emits significant electron flux.

Magnesium oxide and aluminum oxide are the primary materials used for insulation in self-powered neutron detectors. Magnesium oxide has the lower capture cross section of the two materials and is generally preferred for cable insulation. Insulation resistance changes due to both temperature and neutron flux are about the same for both materials providing they are of very high purity.

S.P.N.D.'s are used for in-core power measurements, flux mapping, fuel management, verification of reactor core physics, thermal calculations of flux peaks and power peaks. They provide physical flexibility, permanent operation, low perturbation to flow or flux and high accuracy at low cost. There is no better instrument buy on the market.

Fig. #5



For additional information on the cable portion of self-powered neutron detectors see ARi Bulletin 4.2.

Multiple detector assemblies with self-powered neutron detectors at staggered intervals that are closely controlled to small length dimensional tolerances are available in overall lengths to 46 meters (150 feet). (See Fig. 5)

Manufactured designs have included thermocouples, background detectors, calibration tubes, pressure differential readout tubes in conjunction with S.P.N.D.'s in either a solid or flexible outer protective sheath.

All detectors are tested and certified at ARi Industries, Inc. For additional information on metallurgical and non-destructive capabilities of ARi Industries, Inc. see Bulletin 10.0.

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*TM of International Nickel Corporation

NEUTRON DETECTORS

TABLE I CHARACTERISTICS OF SENSITIVE ELEMENT

Stable Element	Thermal Neutron Cross Sect.	Half Life	Maximum B Energy	B-Current Generated	Burnout Rate In 10^{13} nv	Neutron① Sensitivity
	(Barns)	(Sec)	(MeV)	(A/nv-g)	(%/mo)	(A/nv-cm)
^{103}Rhodium ②	150	42	2.44	1.5×10^{-19}	0.23	1.2×10^{-21}
^{59}Cobalt ③	37	Prompt	—	3.7×10^{-21}	0.1	1.6×10^{-23}
^{51}Vanadium	4.5	226	2.6	8.5×10^{-21}	0.013	7.7×10^{-23}

Notes: ①Values are for 0.5mm emitter diameter in 1.5mm sheath.
②Rhodium also has an 8% yield with half life of 264 sec.
③Cross section is for total neutron interactions not for radiation of beta rays.

TABLE 2 CONFIGURATION OF DETECTOR ①

Sensitive Element	Insulation Material ②	Sheath Material	Wire Dia. mm	Sheath Dia. mm	Overall Dia. Probe Head mm	Emitter Dia. mm
^{103}Rhodium	MgO	Inconel 600 or 300 series St/St	0.25	1.5	1.5	0.5
^{103}Rhodium	MgO		0.15	1.0	1.5	0.5
^{59}Cobalt	MgO		0.25	1.5	4.75	2.0
^{51}Vanadium	MgO		0.25	1.5	2.0	1.0

Notes: ①Emitter length and weight are variable.
②Alternate insulation of Al_2O_3 is available.

HOW TO ORDER

1. **Refer to tables 1 & 2 and select emitter material. Specify its length and diameter.**
2. **Select the collector material (sheath) and specify its diameter for lead section and probe head.**
3. **Select the insulation material.**
4. **Refer to figures 1 and 3 and specify either coaxial or biaxial design, if biaxial, choose either parallel or spiralled construction.**
5. **Specify length of the lead section and the quantity of detectors desired.**
6. **Connectors, plugs, jacks, or flexible leadwire will be attached as required.**
7. **Multiple detector assemblies will be supplied. Ordering information should include the quantity and location of emitters, thermocouples, background detectors and calibration or pressure differential tubes. These assemblies may be bundled but commonly are contained in an oversheath. Lengths can be built up to 46 meters long.**

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